

3.3.1 IDENTIFYING HAZARDS

During the process of the “Hazard Identification”, LOJIC Staff used GIS resources to identify hazards that affect the area. Project Staff researched current hazard data, reports, plans, flood ordinances, past hazard events, flood insurance claims, land use regulations for hazard data, local records of the Emergency Management offices, local newspapers, historical knowledge of committee participants, local officials and community members, as well as GIS information from LOJIC and HAZUS-MH. Two Committee meetings focused on identifying the hazards and data collection. Members of the Planning Team and Advisory Committee provided rich sources of data. Project Staff also talked to experts from federal, state, regional, and local agencies and universities.

Additional research used to identify hazards included interviews of knowledgeable officials and residents in the planning area, the use of FEMA and other web based databases and information sources that identify hazards by geographic locations, Corps of Engineers flood data, Flood Insurance Rate Maps (FIRM), Flood Insurance Studies (FIS), GIS, and additional available historic data including information on past hazard events.

Natural hazards in the U. S. occur in many forms. They can be weather related such as flash floods, severe thunderstorms (hail, wind, & tornadoes), severe winter storms (snow, ice, & frigid temperatures), and coastal storms (hurricanes, storm surges, & tsunamis).

- Geological hazards include volcanoes, earthquakes, and landslides.
- Climatological hazards include drought, excessive heat, and wildfires.
- Topography and hydrology can affect riverine flooding from upstream rain or snow events.
- Man made dams, dikes, and floodwalls can be a source of inundation or flooding if they fail.

A list of U. S. natural hazards includes:

- *Avalanche*
- *Coastal Storms*
- Dam Failure
- Drought
- Earthquake
- Extreme Heat
- Flood
- Hailstorm
- *Hurricane*
- *Mine Subsidence*
- Severe Winter Storm
- Tornado
- *Tsunami*

- *Volcano*
- *Wildfire*
- *Windstorm*

Natural Hazards not Identified in the Louisville Metro Plan: Some natural hazards have little or no affect on the Louisville Metro area or in Kentucky and will not be addressed in this plan (*italicized above*). The hazards showed negligible impact and were not part of federal disaster declarations. This determination does not preclude the plan from including these hazards in future updates of the plan as new information is discovered concerning these types of hazards. Any new information on hazard identification will be included in future updates of this plan.

Following are the natural hazards that will *not* be addressed in the Louisville Metro All Hazards Mitigation Plan.

- Avalanche
- Coastal Storms
- Hurricane
- Mine Subsidence
- Tsunami
- Volcano

Some of these hazards are interrelated, and some consist of hazardous elements that are not listed separately. This section provides general descriptions for each of the emphasized hazards along with their hazardous elements.

Avalanche: The topography and climate of the Louisville Metro area are not conducive to the occurrence of avalanches. No historical events have been recorded in the Louisville Metro area; and, as a result, this hazard will not be addressed in the plan.

Coastal Storms: The Louisville Metro area is more than 400 miles from the Gulf of Mexico coast and over 500 miles from the Atlantic Ocean coast. The immediate effects of coastal storms (hurricanes, storm surge and tsunamis) are not felt in the Louisville Metro area. The secondary effects or remnants of hurricanes may produce severe thunderstorms and flooding in the Louisville Metro area and those hazards will be addressed.

Mine Subsidence: Mine subsidence is defined as the collapse of underground coalmines resulting in direct damage to a surface structure. Land subsidence occurs when the ground sinks to a lower than normal level. Louisville Metro has no active mines and will cover the topic of Land Subsidence under Karst/Sinkholes.

Volcanoes: More than 50 volcanoes in the U. S. have erupted one or more times in the past 200 years. Volcanoes produce a wide variety of hazards that can kill people and destroy property. Active volcanoes in North America are in California, Oregon, Washington, Alaska, Mexico, Canada, and the Caribbean islands. Large explosive eruptions can endanger people and property hundreds of miles away and even affect global climate. However, there are no active volcanoes within 1,000 miles of the Louisville Metro area. Volcanic activity as a hazard is judged to be minimal and will not be addressed in this plan.

Natural Hazards Identified in the Louisville Metro Plan: The Plan includes natural hazards where there is a historical record of damage caused to people and property or where the potential for such damage exists. Due to Louisville's climate, geology, and geographical setting, the metro area is vulnerable to a wide array of natural hazards that threaten life and property.

Through research of the Louisville Metro Emergency Operations Plan (EOP), historic impacts, past federal disaster declarations, probability rates, dollar losses to date, and discussions with key agencies, the following twelve hazards are identified in the Plan. These natural hazards, in alphabetical order, include:

- Dam Failure
- Drought
- Earthquake
- Extreme Heat
- Flood
- Hailstorm
- Karst/Sinkhole/Land Subsidence
- Landslide
- Severe Storm
- Severe Winter Storm
- Tornado
- Wildfires

Following are detailed discussions of each hazard.

Dam / Levee Failure

Description: Kentucky statute KRS 150.100 defines a dam as any artificial barrier including appurtenant works that do, or can, impound or divert water and:

- Is 25 feet or more high from the natural bed of the stream or watercourse at the downstream toe of the barrier, as determined by the Natural Resources and Environmental Protection Cabinet;
- Has or will have an impounding capacity of 50 acre feet or more at the maximum water storage elevation.

In the U. S.

Currently, there are about 2,000 "unsafe" dams in the U.S. There are unsafe dams in almost every state. A majority of states and federal agencies define an "unsafe" dam as one that has been found to have deficiencies that leave it more susceptible to failure.

There are about 80,000 dams in the U. S., the majority of which are privately owned. Other owners are state and local authorities, public utilities, and federal agencies. The benefits of dams are numerous; they provide water for drinking, navigation, and agricultural irrigation. Dams also provide hydroelectric power and create lakes for fishing and recreation. Most important; dams save lives by preventing/reducing floods.

If dams have many benefits, they can also pose a risk to communities if not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam is capable of causing loss of life and great property damage if there are people downstream of the dam. Historically, dams that failed had some deficiency, as characterized above, which caused the failure. These dams are typically termed "unsafe". The National Dam Safety Program is dedicated to protecting the lives of American citizens and their property from the risks associated with the development, operation, and maintenance of America's dams.

Dam-and Levee-Failure Flooding are potentially the worst flood events. A dam failure is usually the result of neglect, poor design, or structural damage caused by a major event such as an earthquake. When a dam fails, an excess amount of water is suddenly let loose downstream, destroying anything in its path. Many dams and levees are built for flood protection. They usually are engineered to withstand a flood with a computed risk of occurrence. For example, a dam or levee may be designed to contain a flood at a location on a stream that has a certain probability of occurring in any one year. If a larger flood occurs, then that structure may be overtopped. If during the overtopping the dam or levee fails or is washed out, the water behind it is released and becomes a flash flood. Failed dams or levees can create floods that are catastrophic to life and property because of the tremendous energy of the released water.

Dam Types

Manmade dams may be classified by:

- 1) The type of materials used;
- 2) The methods used in construction;
- 3) The slope or cross-section of the dam;
- 4) The way the dam resists water pressure forces;
- 5) The means for controlling seepage; and/or
- 6) The purpose of the dam.

Materials used for dams may include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, and/or miscellaneous materials (such as plastic or rubber).

- *Embankment dams* are the most common type of dam in use today. Materials include natural soil or rock, or waste materials obtained from mining or milling operations. An embankment dam is termed an “earth-fill” or “rock-fill” dam depending on whether it is comprised of compacted earth or of dumped rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type and strength of the materials from which the dam is made.
- *Concrete dams* may be categorized as gravity or arch dams according to the design used to resist the stress of reservoir water pressure. Concrete gravity dams use the mass weight of concrete and friction to resist reservoir water pressure. A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation through vertical or sloping buttresses.
- *Concrete arch dams* are typically thin in cross-section. The reservoir water forces acting on an arch dam are carried laterally into the abutments. The shape of the arch may resemble a segment of a circle or an ellipse, and the arch may be curved in the vertical plane as well. Such dams are usually constructed of a series of thin vertical layers that are keyed together; barriers to stop water from flowing are provided between layers.
- *Coal impoundments* are defined by the Mining Safety and Health Administration (MSHA) as any structure associated with coal mining operations built to impound water and, are either at least 20 feet high, or capable of impounding at least 20 acre feet of water. Coal impoundments store coal slurry (wastewater and impurities that result from coal washing and processing). A bulkhead or embankment is made of coarse coal refuse and acts as a dam. Behind it lies a pond of coal slurry. Sediment settles out of this turbid mixture, filling the pond, while wastewater is recycled back into the coal washing process. The sizes of the ponds and bulkheads vary, but pond basins are often hundreds of feet deep and hold millions of gallons of slurry. As of this year, coal impoundment failures have resulted in property damage, environmental contamination and, in one case, loss of life.

Dam Facts

- The federal government owns only 2.7% of the nation’s dams.

- 81% of the dams in the inventory are earthen dams.
- 1,595 significant hazard dams are within one mile of a downstream city.
- The average age for a dam is 40 years.

Drought

Description: A drought is defined as the cumulative deficit of precipitation relative to what is normal for a region over an extended period of time. Unlike other natural hazards, a drought is a non-event that evolves as a prolonged dry spell. Droughts occur when a long period passes without substantial rainfall. A heat wave combined with a drought is a very dangerous situation.

In the U. S.

Droughts can lead to economic losses such as unemployment, decreased land values, and Agro-business losses. In 1998, over 2 billion dollars in property loss was credited to drought in the U. S.

When a drought begins or ends may be difficult to determine. A drought can be short, lasting just a few months, or persist for years before climatic conditions return to normal. While drought conditions can occur at any time throughout the year, the most apparent time is during the summer months. High temperatures, prolonged high winds, and low relative humidity can aggravate drought conditions.

Because the impacts of a drought accumulate slowly at first, a drought may not be recognized until it has become well established. The many aspects of drought reflect its varied impacts on people and the environment. While the impacts of precipitation deficit may be extensive, it is the deficit, not the impacts, that defines a meteorological drought.

Primary Effects

- Crop failure is the most apparent effect of drought in that it has a direct impact on the economy and, in many cases, health (nutrition) of the population that is affected by it. Due to a lack of water and moisture in the soil, many crops will not produce normally or efficiently and, in many cases, may be lost entirely.
- Water shortage is a very serious effect of drought in that the availability of potable water is severely decreased when drought conditions persist. Springs, wells, streams, and reservoirs have been known to run dry due to the decrease in ground water, and, in extreme cases, navigable rivers have become unsafe for navigation as a result of drought.

Secondary Effects

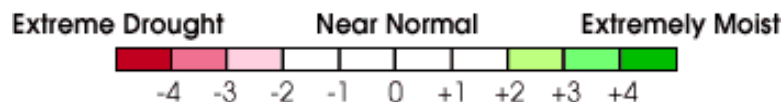
- Fire susceptibility is increased with the absence of moisture associated with a drought. Dry conditions have been known to promote the occurrence of widespread wildfires.

Tertiary Effects

- Environmental degradation in the forms of erosion and ecological damage can be seen in cases of drought. As moisture in topsoil decreases and the ground becomes dryer, the susceptibility to windblown erosion increases. In prolonged drought situations, forest root systems can be damaged and/or destroyed resulting in loss of habitat for certain species. In addition, prolonged drought conditions may result in loss of food sources for certain species.
- In prolonged drought situations the soil surrounding structures subsides, sometimes creating cracks in foundations and separation of foundations from above ground portions of the structure.

The Palmer Drought Severity Index (PDSI) shows the relative dryness or wetness effecting water sensitive economies. The PDSI indicates the prolonged and abnormal moisture deficiency or excess.

Palmer Drought Severity Index



The PDSI is an important climatological tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. It can be used to help delineate disaster areas and indicate the availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and potential intensity of forest fires.

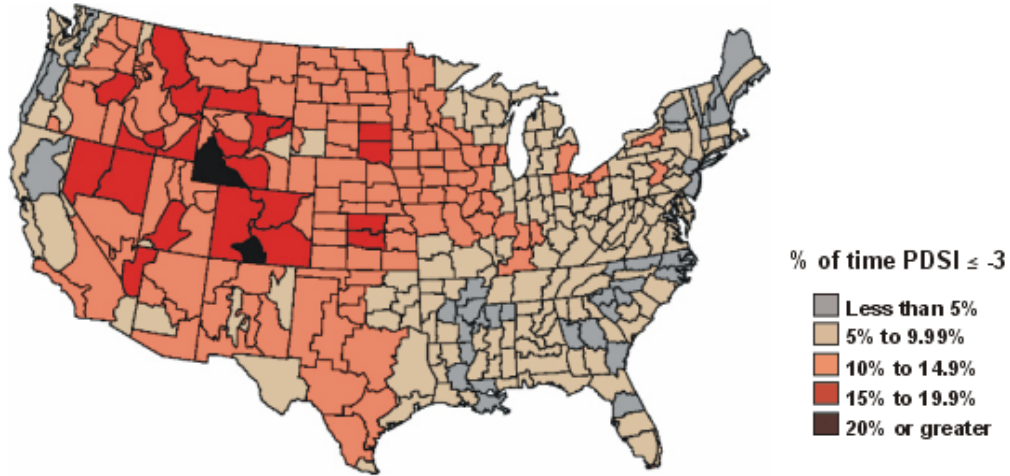
Palmer Classifications System (PDSI)	
+4.0 in. or more	Extremely wet
3.0 in to 3.99 in	Very wet
2.0 in to 2.99 in	Moderately wet
1.0 in to 1.99 in	Slightly wet
0.5 in to 0.99 in	Incipient wet spell
0.49 in to -0.49 in	Near normal
-0.5 in to -0.99 in	Incipient dry spell
-1.9 in to -1.99 in	Mild drought
-2.0 in to -2.99 in	Moderate drought
-3.0 in to -3.99 in	Severe drought
-4.0 in or less	Extreme drought
<i>(Source: National Oceanic and Atmospheric Association (NOAA))</i>	

Drought is measured in the Palmer Drought Severity Index according to the level of recorded precipitation against the average, or normal, amount of precipitation for a region.

Palmer Drought Severity Index

1895–1995

Percent of time in severe and extreme drought



SOURCE: McKee et al. (1993); NOAA (1990); High Plains Regional Climate Center (1996)
Albers Equal Area Projection; Map prepared at the National Drought Mitigation Center

In the 100-year map for 1895 to 1995, the Bluegrass Zone is within the 5% to 9.99% range. For the 10-year interval of 1985-1995, the Bluegrass Zone had a severe drought rating of 5% to 9.9%.

Earthquake

Description: An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface. For hundreds of millions of years, the forces of plate tectonics have shaped the Earth as the huge plates that form the Earth's surface move slowly over, under, and past each other. Sometimes the movement is gradual while at other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free releasing the stored energy and producing seismic waves generating an earthquake. The areas of greatest tectonic instability occur at the perimeters of the slowly moving plates, as these locations are subjected to the greatest strains from plates traveling in opposite directions and at different speeds. However, some earthquakes occur in the middle of plates.

In the U. S.

Earthquakes strike suddenly and without warning and can occur at any time of the year and at any time of the day or night. On a yearly basis, 70 to 75 damaging earthquakes occur throughout the world. Estimates of losses from a future earthquake in the U. S. approach \$200 billion.

There are 45 states and territories in the U. S. at moderate to very high risk from earthquakes.

Earthquakes result from crustal strain, volcanism, landslides, or the collapse of caverns. An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Ground motion, the movement of the earth's surface during earthquakes or explosions, is the catalyst for most of the damage during an earthquake. Produced by waves generated by a sudden slip of a fault or sudden pressure at the explosive source, ground motion travels through the earth and along its surface. Ground motions are amplified by soft soils overlying hard bedrock, referred to as ground motion amplification. Ground motion amplification can cause an excess amount of damage during an earthquake, even to sites very far from the epicenter.

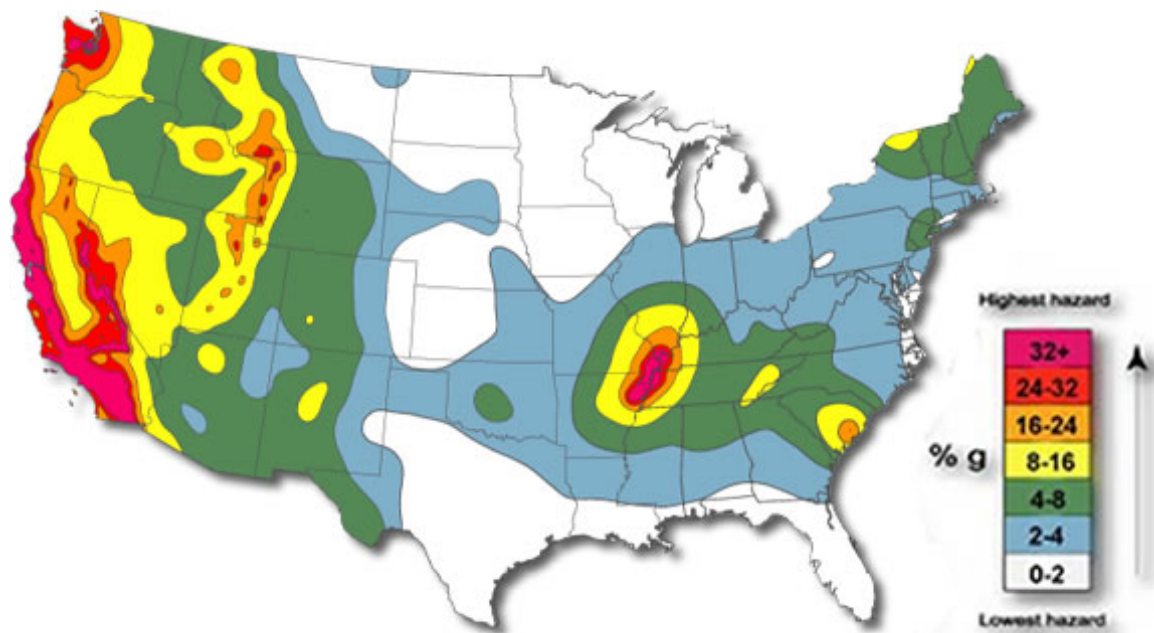
Earthquakes can affect hundreds of thousands of square kilometers; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area. Ground shaking from earthquakes can collapse buildings and bridges, disrupt gas, electric, phone service, and sometimes trigger landslides, avalanches, flash floods, fires, and destructive ocean waves (tsunamis). During an earthquake, buildings with foundations resting on unconsolidated landfill and other unstable soil, and trailers and homes not tied to their foundations are at risk because they can be shaken off their mountings. When an earthquake occurs in a populated area, it may cause deaths, injuries, and extensive property damage.

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends

upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault site and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quick sand. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

The Northridge, California, earthquake of January 17, 1994, struck a modern urban environment generally designed to withstand the forces of earthquakes. Its economic cost, nevertheless, has been estimated at \$20 billion. Fortunately, relatively few lives were lost. Exactly one year later, Kobe, Japan, a densely populated community less prepared for earthquakes than Northridge, was devastated by the most costly earthquake ever to occur. Property losses were projected at \$96 billion, and at least 5,378 people were killed. These two earthquakes tested building codes and construction practices, as well as emergency preparedness and response procedures.

California experiences the most frequent damaging earthquakes. However, Alaska experiences the greatest number of large earthquakes-most located in uninhabited areas. The largest earthquakes felt in the U. S. were along the New Madrid Fault in Missouri, where a three-month long series of quakes from 1811 to 1812 included three quakes larger than a magnitude of 8 on the Richter Scale. These earthquakes were felt over the entire eastern U. S., with Missouri, Tennessee, Kentucky, Indiana, Illinois, Ohio, Alabama, Arkansas, and Mississippi experiencing the strongest ground shaking.



Earthquake probability map from USGS

Earthquake Types

Earthquakes are measured in terms of their magnitude and intensity. *Magnitude* is measured using the Richter Scale that describes the energy release of an earthquake through a measure of shock wave amplitude. *Intensity* is most commonly measured using the Modified Mercalli Intensity (MMI) Scale.

The Richter magnitude scale measures an earthquake's magnitude using an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude. The earthquake's magnitude is expressed in whole numbers and decimal fractions. Each whole number increase in magnitude represents a 10-fold increase in measured wave amplitude, or a release of 32 times more energy than the preceding whole number value.

The Modified Mercalli Scale measures the effect of an earthquake on the Earth's surface. Composed of 12 increasing levels of intensity that range from unnoticeable shaking to catastrophic destruction, the scale is designated by Roman numerals. The roman numerals, with I corresponding to imperceptible (instrumental) events, IV corresponding to moderate (felt by people awake), to XII for catastrophic (total destruction). The lower values of the scale detail the manner in which people feel the earthquake, while the increasing values are based on observed structural damage. The intensity values are assigned after gathering responses to questionnaires administered to postmasters in affected areas in the aftermath of the earthquake.

A detailed description of the Modified Mercalli Scale of Earthquake Intensity and its correspondence to the Richter Scale is given in the table.

o Modified Mercalli Intensity Scale for Earthquakes			
Scale	Intensity	Description	Corresponding Richter Scale magnitude
I	Instrumental	Detected only on seismographs	
II	Feeble	Some people feel it	<4.2
III	Slight	Felt by people resting; like a truck rumbling by	
IV	Moderate	Felt by people walking	
V	Slightly Strong	Sleepers awake; church bells ring	<4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves	<5.4
VII	Very Strong	Mild Alarm; walls crack; plaster falls	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	<6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides are widespread	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards	<8.1

Earthquake Facts

Although earthquakes in the central or eastern U. S. occur less frequently, they effect much larger areas than earthquakes of similar magnitude in the western U. S. For example, the San Francisco, California earthquake of 1906 (magnitude 7.8) was felt 350 miles away in the middle of Nevada, whereas the New Madrid earthquake of December 1811 (magnitude 8.0) rang church bells in Boston, Massachusetts, 1,000 miles away. Differences in geology east and west of the Rocky Mountains cause this strong contrast.

Likelihood of Occurrence

The goal of earthquake prediction is to give warning of potentially damaging earthquakes early enough to allow appropriate response to the disaster, enabling people to minimize loss of life and property. The USGS conducts and supports research on the likelihood of future earthquakes. This research includes field, laboratory, and theoretical investigations of earthquake mechanisms and fault zones. A primary goal of earthquake research is to increase the reliability of earthquake probability estimates. Ultimately, scientists would like to be able to specify a high probability for a specific earthquake, on a particular fault, within a particular year. Scientists estimate earthquake probabilities in two ways: by studying the history of large earthquakes in a specific area, and by the rate at which strain accumulates in the rock.

Scientists study the past frequency of large earthquakes in order to determine the future likelihood of similar large shocks. For example, if a region has experienced four magnitude 7 or larger earthquakes during 200 years of recorded history, and if these shocks occurred randomly in time, then scientists would assign a 50 percent probability (that is, just as likely to happen as not to happen) to the occurrence of another magnitude 7 or larger quake in the region during the next 50 years.

But in many places, the assumption of random occurrence with time may not be true, because when strain is released along one part of the fault system, it may actually increase on another part. Four magnitude 6.8 or larger earthquakes and many magnitude 6 - 6.5 shocks occurred in the San Francisco Bay region during the 75 years between 1836 and 1911. For the next 68 years (until 1979), no earthquakes of magnitude 6 or larger occurred in the region. Beginning with a magnitude 6.0 "shock" in 1979, the earthquake activity in the region increased dramatically; between 1979 and 1989, there were four, magnitude 6 or greater earthquakes, including the magnitude 7.1 Loma Prieta earthquake. This clustering of earthquakes leads scientists to estimate that the probability of a magnitude 6.8 or larger earthquake occurring during the next 30 years in the San Francisco Bay region is about 67 percent (twice as likely as not).

Extreme Heat

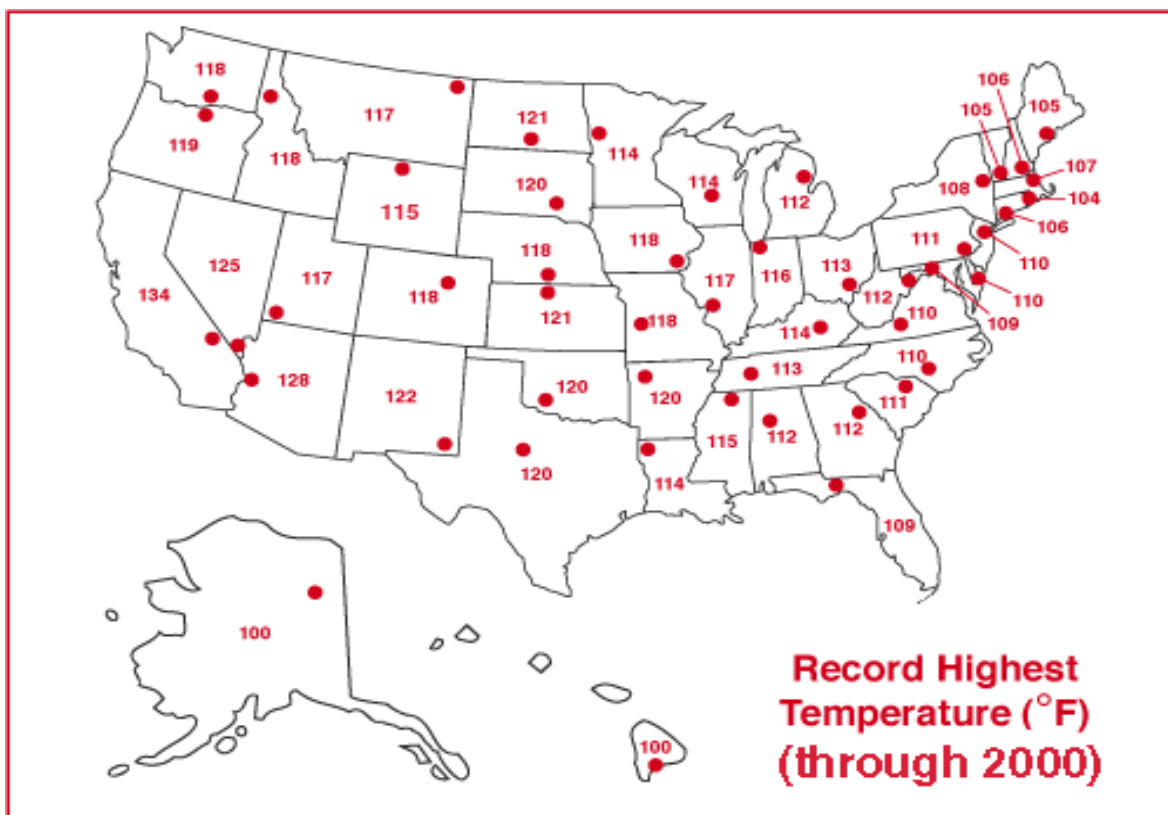
Description: Temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks are defined as extreme heat.

Heat Index

Our bodies dissipate heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and as a last resort, by panting, when blood is heated above 98.6°F. Sweating cools the body through evaporation. However, high relative humidity retards evaporation, robbing the body of its ability to cool itself.

In the U. S.

Heat kills by taxing the human body beyond its abilities. In a normal year, about 175 Americans succumb to the demands of summer heat. In the 40-year period from 1936 through 1975, nearly 20,000 people were killed in the U. S. by the effects of heat and solar radiation. In the disastrous heat wave of 1980, more than 1,250 people died.



Temperature (F) versus Relative Humidity (%)						
°F	90%	80%	70%	60%	50%	40%
80	85	84	82	81	80	79
85	101	96	92	90	86	84
90	121	113	105	99	94	90
95		133	122	113	105	98
100			142	129	118	109
105				148	133	121
110						135

HI	Possible Heat Disorder:
80°F - 90°F	Fatigue possible with prolonged exposure and physical activity.
90°F - 105°F	Sunstroke, heat cramps and heat exhaustion possible.
105°F - 130°F	Sunstroke, heat cramps, and heat exhaustion likely, and heat stroke possible.
130°F or greater	Heat stroke highly likely with continued exposure.

(<http://www.crh.noaa.gov/pub/heat.htm>)

(Due to the nature of the heat index calculation, the values in the table have an error +/- 1.3F.)

NOAA's National Weather Service Heat Index Program

Based on the latest research findings, the NWS has devised the "Heat Index" (HI). The HI, given in degrees F, is an accurate measure of how hot it really feels when relative humidity (RH) is added to the actual air temperature. The NWS will initiate alert procedures when the HI is expected to exceed 105°- 110°F for at least two consecutive days. The Heat Index is the temperature the body feels when heat and humidity are combined. The chart below shows the HI that corresponds to the actual air temperature and relative humidity.

Considering the tragic death toll which occurred in 1980, the NWS has stepped up its efforts to alert more effectively the general public and appropriate authorities to the hazards of heat waves-those prolonged excessive heat/humidity episodes.

Heat Index/Heat Disorders Impacts	
Heat Index	Heat Disorders I
130° or Higher	Heatstroke/sunstroke highly higher likely with continued exposure
105° - 130°	Sunstroke, heat cramps or heat exhaustion likely, and heatstroke possible with prolonged exposure

Heat Index/Heat Disorders Impacts	
Heat Index	Heat Disorders I
	and/or physical activity
90° - 105°:	Sunstroke, heat cramps and heat exhaustion possible with prolonged exposure and/or physical activity
80° - 90°	Fatigue possible with prolonged exposure and/or physical activity

Types of Heat Disorder Symptoms

When heat gain exceeds the level the body can remove, body temperature begins to rise, and heat related illnesses and disorders might develop. Elderly persons, small children, chronic invalids, those on certain medications and persons with weight and alcohol problems are particularly susceptible to heat reactions, especially during heat waves in areas where a moderate climate usually prevails. Heat disorders generally have to do with a reduction or collapse of the body's ability to shed heat by circulatory changes and sweating, or a chemical (salt) imbalance caused by too much sweating. When heat gain exceeds the level the body can remove, or when the body cannot compensate for fluids and salt lost through perspiration, the temperature of the body's inner core begins to rise and heat-related illness may develop.

Ranging in severity, heat disorders share one common feature: the individual has overexposed or over exercised for his age and physical condition in the existing thermal environment. Studies indicate that, other things being equal, the severity of heat disorders tend to increase with age. Heat cramps in a 17-year-old may be heat exhaustion in someone 40, and heat stroke in a person over 60.

- *Sunburn*: Redness and pain. In severe cases swelling of skin, blisters, fever, and headaches. Sunburn, with its ultraviolet radiation burns, can significantly retard the skin's ability to shed excess heat.
- *Heat Cramps*: Painful spasms usually in muscles of legs and abdomen possible. Heavy sweating.
- *Heat Exhaustion*: Heavy sweating, weakness, skin cold, pale and clammy. Pulse thready. Normal temperature possible. Fainting and vomiting.
- *Heat Stroke (or sunstroke)*: High body temperature (106° F. or higher). Hot dry skin. Rapid and strong pulse. Possible unconsciousness.

Flood

Description: A flood is a natural event for rivers and streams and is caused in a variety of ways. Floods can be slow, or fast rising, but generally develop over a period of days. Winter or spring rains, coupled with melting snows, can fill river basins too quickly. Torrential rains from decaying hurricanes or other tropical systems can also produce flooding. The excess water from snowmelt, rainfall, or storm surge accumulates and overflows onto the banks and adjacent floodplains.

Floods are generally the result of excessive precipitation, and can be classified under two categories: *flash floods*, the product of heavy localized precipitation in short time period over a given location; and *general floods*, caused by precipitation over a longer time period and over a given river basin.

The severity of a flooding event is determined by a combination of stream and river basin topography and physiography, precipitation and weather patterns, recent soil moisture conditions and the degree of vegetative clearing. Flood currents also possess tremendous destructive power as lateral forces can demolish buildings and erosion can undermine bridge foundations and footings, leading to the collapse of structures.

Flash flooding events usually occur within minutes or hours of heavy amounts of rainfall, from a dam or levee failure, or from a sudden release of water held by an ice jam.

General floods are usually longer-term events and may last for several days. The primary types of general flooding include riverine flooding, coastal flooding, and urban flooding.

Periodic flooding of lands adjacent to rivers, streams, and shorelines is a natural and inevitable occurrence that can be expected to take place based upon established recurrence intervals. The recurrence interval of a flood is defined as the average time interval, in years, expected between a flood event of a

In the U. S.

Flooding is the most frequent and costly natural hazard in the U.S. Property damage from flooding now totals over \$1 billion each year in the U.S. More than \$4 billion is spent on flood damage in the U.S. each year.

During the 20th century, floods were the number one natural disaster in the U.S. in terms of number of lives lost and property damage, and floods are the number one weather-related killer. Flooding has caused the deaths of more than 10,000 people since 1900.

What is a Flood?

A flood, as defined by the National Flood Insurance Program (NFIP) is a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area, or of two or more properties from:

- Overflow of inland or tidal waters;
- Unusual and rapid accumulation or runoff of surface waters from any source;
- A mudflow; or,
- A collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood.

particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval. A "floodplain" is the lowland area adjacent to a river, lake, or ocean.

Floodplains are designated by the frequency of the flood that is large enough to cover them. One way of expressing the flood frequency is the chance of occurrence in a given year, which is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1% chance of occurring in any given year.

Types

Floods are the result of a multitude of naturally occurring and human-induced factors, but they all can be defined as the accumulation of too much water in too little time in a specific area. Types of floods include regional floods, river or riverine floods, flash floods, urban floods, ice-jam floods, storm-surge floods, and debris, landslide, and mudflow floods. For information on dam- and levee-failure floods, see Dam Failure in this section of the Plan.

- *Regional Flooding* can occur seasonally when winter or spring rains coupled with melting snow fill river basins with too much water too quickly. The ground may be frozen, reducing infiltration into the soil and thereby increasing runoff. Extended wet periods during any part of the year can create saturated soil conditions, after which any additional rain runs off into streams and rivers, until river capacities are exceeded. Regional floods are many times associated with slow-moving, low-pressure or frontal storm systems including decaying hurricanes or tropical storms.
- *River or Riverine Flooding* is a high flow or overflow of water from a river or similar body of water, occurring over a period of time too long to be considered a flash flood. Riverine

Common Flood-Related Terms

100-Year Flood Plain. The area that has a 1% chance, on average, of flooding in any given year. (Also known as the Base Flood.)

500-Year Flood Plain. The area that has a 0.2% chance, on average, of flooding in any given year.

Base Flood. Represents a compromise between minor floods and the greatest flood likely to occur in a given area. The elevation of water surface resulting from a flood that has a 1% chance of occurring in any given year.

Floodplain. The land area adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. This area, if left undisturbed, acts to store excess floodwater. The floodplain is made up of two sections: the floodway and the flood fringe.

Floodway. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved, in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot." The floodway carries the bulk of the floodwater downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures that would obstruct or divert flood flows onto other properties.

Flood Fringe. The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward.

flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river.

- *Flash Floods* are quick-rising floods that usually occur as the result of heavy rains over a short period of time, often only several hours or even less. Several factors can contribute to flash flooding. Among these are rainfall intensity, rainfall duration, surface conditions, and topography and slope of the receiving basin. Flash floods can occur within several seconds to several hours and with little warning. They can be deadly because they produce rapid rises in water levels and have devastating flow velocities. Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common in urbanized areas where much of the ground is covered by impervious surfaces.
- *Urban Flooding* is possible when land is converted from fields or woodlands to roads and parking lots; thus, losing its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force. During periods of urban flooding, streets can become swift moving rivers and basements can fill with water. Storm drains often back up with vegetative debris causing additional, localized flooding.
- *Ice-Jam Flooding* occurs on rivers that are totally or partially frozen. A rise in stream stage will break up a totally frozen river and create ice flows that can pile up on channel obstructions such as shallow riffles, log jams, or bridge piers. The jammed ice creates a dam across the channel over which the water and ice mixture continues to flow, allowing for more jamming to occur. Backwater upstream from the ice dam can rise rapidly and overflow the channel banks. Flooding moves downstream when the ice dam fails, and the water stored behind the dam is released. At this time the flood takes on the characteristics of a flash flood, with the added danger of ice flows that, when driven by the energy of the flood-wave, can inflict serious damage on structures. An added danger of being caught in an ice-jam flood is hypothermia, which can quickly kill.
- *Storm-surge flooding* is water that is pushed up onto otherwise dry land by onshore winds. Friction between the water and the moving air creates drag that, depending upon the distance of water (fetch) and the velocity of the wind, can pile water up to depths greater than 20 feet. Intense, low-pressure systems and hurricanes can create storm-surge flooding. The storm surge is unquestionably the most dangerous part of a hurricane as pounding waves create very hazardous flood currents.
- *Debris, Landslide, and Mudflow Flooding* is created by the accumulation of debris, mud, rocks, and/or logs in a channel, forming a temporary dam.

Flooding occurs upstream as water becomes stored behind the temporary dam and then becomes a flash flood when the dam is breached and rapidly washes away. Landslides can create large waves on lakes or embayments and can be deadly.

Urban areas are susceptible to flash floods because a high percentage of the surface area is composed of impervious streets, roofs, and parking lots where runoff occurs very rapidly. Mountainous areas also are susceptible to flash floods, as steep topography may funnel runoff into a narrow canyon. Floodwaters accelerated by steep stream slopes can cause the flood-wave to move downstream too fast to allow escape, resulting in many deaths.

Factors determining the severity of floods include:

- Rainfall intensity and duration
 - A large amount of rain over a short time can result in flash flooding
 - Small amounts may cause flooding where the soil is saturated
 - Small amounts may cause flooding if concentrated in an area of impermeable surfaces
- Topography and ground cover
- Water runoff is greater in areas with steep slopes and little vegetation

Flood Facts for the U. S.

- On average, there are about 145 deaths each year due to flooding. 80% of flood deaths occur in vehicles, and most happen when drivers try to navigate through floodwaters.
- Only six inches of rapidly moving floodwater can knock a person down and a mere two feet of water can float a vehicle.
- One-third of flooded roads and bridges are so damaged by water that any vehicle trying to cross stands only a 50% chance of making it to the other side.
- Six to eight million homes are located in flood-prone areas.
- About one-third of insurance claims for flood damages are for properties located outside identified flood hazard areas.

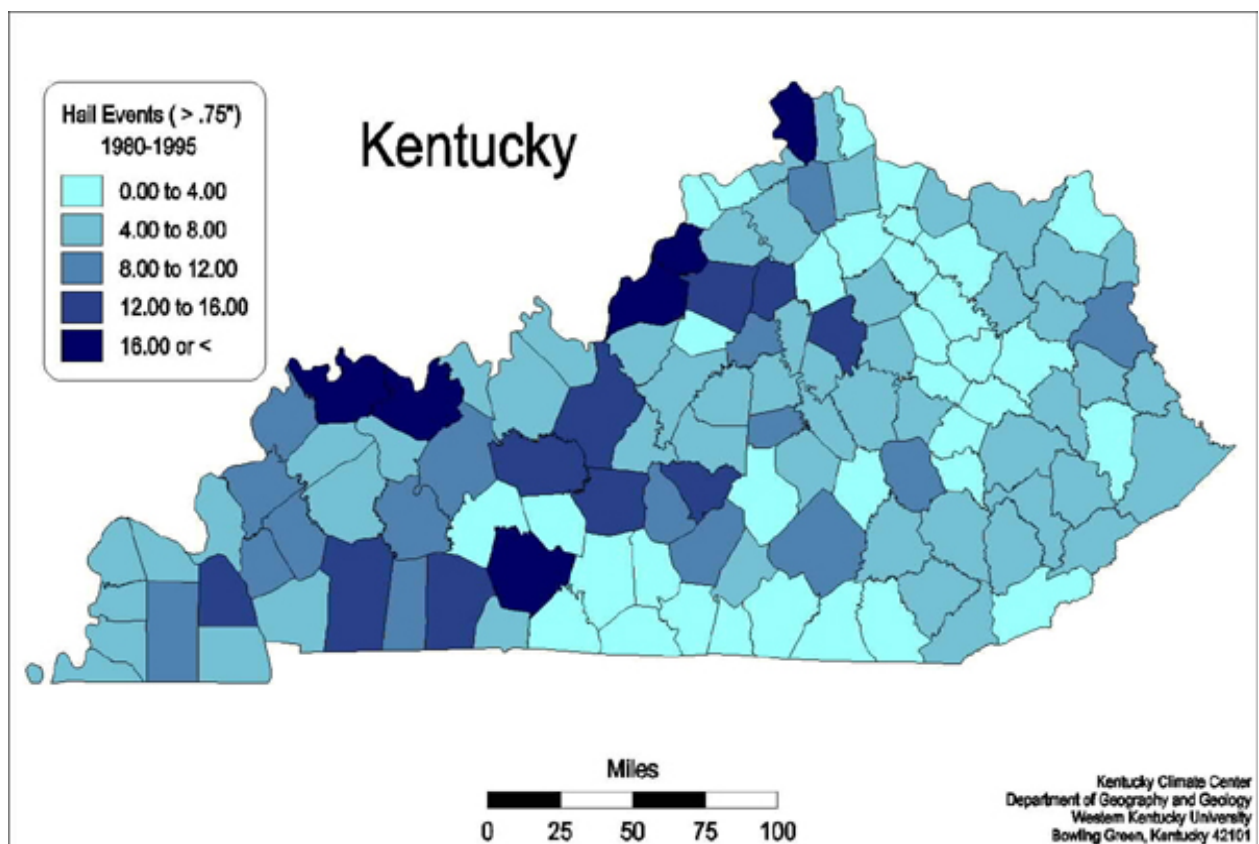
Hailstorm

Description: Hail is precipitation in the form of spherical or irregular pellets of ice larger than 5 millimeters (0.2 inches) in diameter (*American Heritage Dictionary*).

Hail is a somewhat frequent occurrence associated with severe thunderstorms. Hailstones grow as ice pellets are lifted by updrafts, and collect super-cooled water droplets. As the pellets grow, hailstones become heavier and begin to fall. Sometimes, hailstones are caught by successively stronger updrafts and are re-circulated through the cloud growing larger each time the cycle is repeated. Eventually, the updrafts can no longer support the weight of the hailstones. As hailstones fall to the ground, they produce a hail-streak (i.e. area where hail falls) that may be more than a mile wide and a few miles long.

In the U. S.

Hailstones can fall at speeds of up to 120 mph. Hail is responsible for nearly \$1 billion in damage to crops and property each year in the U.S.



(Source: <http://kyclim.wku.edu/climate/>)

Hail Types

Hail is a unique and common hazard capable of producing extensive damage from the impact of these falling objects. Hailstorms occur more frequently during the late spring and early summer months. Most thunderstorms do not produce hail, and ones that do normally produce only small hailstones not more than one-half inch in diameter.

Hail Conversion Chart	
Diameter of Hailstones (inches)	Description
0.50	Marble
0.70	Dime
0.75	Penny
0.88	Nickel
1.00	Quarter
1.25	Half Dollar
1.50	Walnut
1.75	Golf Ball
2.00	Hen Egg
2.50	Tennis Ball
2.75	Baseball
3.00	Tea Cup
4.00	Grapefruit
4.50	Softball

Karst/Sinkhole

Description: Karst is an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams, and caverns. A sinkhole is a natural depression in a land surface communicating with a subterranean passage, generally occurring in limestone regions and formed by solution or by collapse of a cavern roof (*American Heritage Dictionary*).

In the U. S.

Sinkhole collapses are commonly repaired by dumping any available material into the hole. This technique usually diverts water to other locations and lessens the likelihood of collapse.

Karst refers to a type of topography formed in limestone, dolomite, or gypsum by dissolution of these rocks by rain and underground water. It is characterized by closed depressions or sinkholes and underground drainage. During the formation of Karst terrain, water percolating underground enlarges subsurface flow paths by dissolving the rock. As some subsurface flow paths are enlarged over time, water movement in the aquifer changes character from one where ground water flow was initially through small, scattered openings in the rock, to one where most flow is concentrated in a few, well-developed conduits. As the flow paths continue to enlarge, caves may be formed and the ground water table may drop below the level of surface streams. Surface streams may then begin to lose water to the subsurface. As more of the surface water is diverted underground, surface streams and stream valleys become a less conspicuous feature of the land surface and are replaced by closed basins. Funnels or circular depressions called sinkholes often develop at some places in the low points of these closed basins.

Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself. Land subsidence can occur unnoticed because it covers large areas rather than in a small spot, like a sinkhole. Subsidence not only damages structures built immediately above the subsiding area, but also sets up lateral stresses that may severely damage adjacent structures.

Sinkhole Types

- *Cover-Collapse Sinkholes* occur in the soil or other loose material overlying soluble bedrock. Sinkholes that suddenly appear form in two ways. In the first way, the bedrock roof of a cave becomes too thin to support the weight of the bedrock and the soil material above it. The cave roof then collapses, forming a bedrock-collapse sinkhole. Bedrock collapse is rare and the least likely way a sinkhole can form, although it is commonly incorrectly assumed to be the way all sinkholes form. The second way sinkholes can form is much more common and much less dramatic. The sinkhole begins to form when a fracture in the limestone

bedrock is enlarged by water dissolving the limestone. As the bedrock is dissolved and carried away underground, the soil gently slumps or erodes into the developing sinkhole. Once the underlying conduits become large enough, insoluble soil and rock particles are carried away too. Cover-collapse sinkholes can vary in size from 1 or 2 feet deep and wide, to tens of feet deep and wide. The thickness and cohesiveness of the soil cover determine the size of a cover-collapse sinkhole.

- *Collapse sinkholes* occur when the bridging material over a subsurface cavern cannot support the overlying material. The cover collapses into the cavern and a large, funnel-shaped depression forms.
- *Solution sinkholes* result from increased groundwater flow into higher porosity zones within the rock, typically through fractures or joints within the rock. An increase of slightly acidic surface water into the subsurface continues the slow dissolution of the rock matrix, resulting in slow subsidence as surface materials fill the voids.
- *Alluvial sinkholes* are older sinkholes that have been partially filled with marine, wetland, or soil sediments. These features are common in places like Florida, where the water table is shallow, and typically appear as shallow lakes, cypress “domes”, and wetlands.
- *Raveling sinkholes* form when a thick overburden of sediment over a deep cavern caves into the void and pipes upward toward the surface. As the overlying material or “plug” erodes into the cavern, the void migrates upward until the cover can no longer be supported and then subsidence begins.

Sinkhole Flooding

Sinkhole flooding is a naturally occurring event that usually follows the same storms that cause riverine flooding, so it is often not recognized as Karst-related. Flood events will differ not only because of the amount of precipitation, but also because the drainage capacity of individual sinkholes can change, sometimes very suddenly, as the Karst landscape evolves. Sinkholes can also flood when their outlets are clogged, preventing water from being carried away as fast as it flows in. Trash thrown into a sinkhole can clog its throat, as can soil eroded from fields and construction sites, or a natural rock fall near the sinkhole’s opening. Sometimes the conduit itself is too narrow because it has recently (in the geologic sense) captured a larger drainage basin. The reach of a conduit downstream from constriction could carry a higher flow than it is receiving were it not for this restriction.

Sinkholes flood more easily around development (roofs, parking lots, highways), which increases both the total runoff and the rapidity of runoff from a storm. Another reason that sinkholes flood is back-flooding, the outcome when the discharge capacity of the entire Karst conduit network is exceeded. Some up-gradient sinkholes that drain normally during the short, modest accumulation of storms may actually become springs that discharge water during prolonged

rainfall. Sinkhole flooding is one of the more tragic hazards because it affects private residences the most.

Land Surface Indicators of Sinkhole Collapse

- Circular and linear cracks in soil, asphalt, and concrete paving and floors
- Depressions in soil or pavement that commonly result in ponds of water
- Slumping, sagging, or tilting of trees, roads, rails, fences, pipes, poles, sign boards, and other vertical or horizontal structures
- Downward movement of small-diameter vertical or horizontal structures
- Fractures in foundations and walls, often accompanied by jammed doors and windows
- Small conical holes that appear in the ground over a relatively short period of time
- Sudden muddying of water in a well that has been producing clear water
- Sudden draining of a pond or creek

Landslide

Description: Landslides occur when masses of rock, earth, or debris move down a slope. Landslides may be very small or very large, and can move at slow to very high speeds. Many landslides have been occurring over the same terrain since prehistoric times. They are activated by storms and fires and by human modification of the land. New landslides occur because of rainstorms, earthquakes, volcanic eruptions, and various human activities.

In the U. S.

Landslides are a major geologic hazard because they occur in all 50 states causing approximately \$2 billion in damages and 25 to 50 deaths a year.

Mudflows or debris flows differ from landslides because they are rivers of rock, earth, and other debris saturated with water. Mudflows develop when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the earth into a flowing river of mud or "slurry". A slurry can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. A slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. Landslides pose serious threats to highways and structures that support fisheries, tourism, timber harvesting, mining, and energy production as well as general transportation.

Most losses from landslides and soil creep occur in cities developed on gently sloping hillsides. Although a landslide may occur almost anywhere, from man-made slopes to natural, pristine ground, most slides occur in areas that have experienced sliding in the past. All landslides are triggered by similar causes. These can be weaknesses in the rock and soil, earthquake or volcanic activity, the occurrence of heavy rainfall or snowmelt, or construction activity changing some critical aspect of the geological environment. Landslides that occur following periods of heavy rain or rapid snowmelt worsen the accompanying effects of flooding.

Areas that are generally prone to landslide hazards include existing old landslides; the bases of steep slopes; the bases of drainage channels; and developed hillsides where leach-field septic systems are used.

Areas that are typically considered safe from landslides include areas that have not moved in the past; relatively flat-lying areas away from sudden changes in slope; and areas at the top or along ridges, set back from the tops of slopes.

Landslide Types

- *Slides* of soil or rock involve downward displacement along one or more failure surfaces. The material from the slide may be broken into a number of pieces or remain a single, intact mass. Sliding can be rotational, where movement involves turning about a specific point. Sliding can be

translational, where movement is down slope on a path roughly parallel to the failure surface. The most common example of a rotational slide is a slump, which has a strong, backward rotational component and a curved, upwardly-concave failure surface.

- *Flows* are characterized by shear strains distributed throughout the mass of material. They are distinguished from slides by high water content and distribution of velocities resembling that of viscous fluids. Debris flows are common occurrences in much of North America. These flows are a form of rapid movement in which loose soils, rocks, and organic matter, combined with air and water, form a slurry that flows downslope. The term “debris avalanche” describes a variety of very rapid to extremely rapid debris flows associated with volcanic hazards. Mudflows are flows of fine-grained materials, such as sand, silt, or clay, with high water content. A subcategory of debris flows, mudflows contains less than 50 percent gravel.
- *Lateral spreads* are characterized by large elements of distributed, lateral displacement of materials. They occur in rock, but the process is not well-documented and the movement rates are very slow. Lateral spreads can occur in fine-grained, sensitive soils such as quick clays, particularly if remolded or disturbed by construction and grading. Loose, granular soils commonly produce lateral spread through liquefaction. Liquefaction can occur spontaneously, presumably because of changes in pore-water pressures, or in response to vibrations such as those produced by strong earthquakes.
- *Falls and Topples*. Falls occur when masses of rock or other material detach from a steep slope or cliff and descend by free fall, rolling, or bouncing. These movements are rapid to extremely rapid and are commonly triggered by earthquakes. Topples consist of forward rotation of rocks or other materials about a pivot point on a hill slope. Toppling may culminate in abrupt falling, sliding, or bouncing, but the movement is tilting without resulting in collapse. Data on rates of movement and control measures for topples is sparse

Severe Storm (Thunderstorm and Lightning)

Descriptions:

A *thunderstorm* is formed from a combination of moisture, rapidly rising warm air and a force capable of lifting air such as a warm and cold front, a sea breeze or a mountain. All thunderstorms contain lightning and may occur singly, in clusters or in lines. Thus, it is possible for several thunderstorms to affect one location in the course of a few hours. Some of the most severe weather occurs when a single thunderstorm affects one location for an extended period time. The NWS considers a thunderstorm as severe if it develops $\frac{3}{4}$ inch hail or 50-knot (58 mph) winds.

Lightning is an electrical discharge that results from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt". This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning reaches a temperature approaching 50,000 degrees Fahrenheit in a split second. The rapid heating and cooling of air near the lightning causes thunder.

In the U. S.

Thunderstorms affect relatively small areas as the average storm is 15 miles in diameter and lasts an average of 30 minutes. Nearly 1,800 thunderstorms are occurring at any moment around the world, however, of the estimated 100,000 thunderstorms that occur each year in the U. S. only about 10 percent are classified as severe.

Lightning is the second most frequent killer in the U.S. Each year, lightning is responsible for an average of 93 deaths (more than tornadoes), 300 injuries, and several hundred million dollars in damage to property.

Radar observers use the intensity of the radar echo to distinguish between rain showers and thunderstorms. Lightning detection networks routinely track cloud-to-ground flashes, and therefore thunderstorms.

Thunderstorms occur when clouds develop sufficient upward motion and are cold enough to provide the ingredients (ice and super cooled water) to generate and separate electrical charges within the cloud. The cumulonimbus cloud is the perfect lightning and thunder factory, earning its nickname, "thunderhead".

All thunderstorms are dangerous and capable of threatening life and property in localized areas. Every thunderstorm produces lightning, which results from the buildup and discharge of electrical energy between positively and negatively charged areas.

While thunderstorms and lightning can be found throughout the U. S., they are most likely to occur in the central and southern states. Thunderstorms can also produce large, damaging hail, which causes nearly \$1 billion in damage to property and crops annually. Thunderstorms are also capable of producing

tornadoes, wind, heavy rain that can lead to flash flooding, and hail. These hazards will be addressed as individual hazards in the plan.

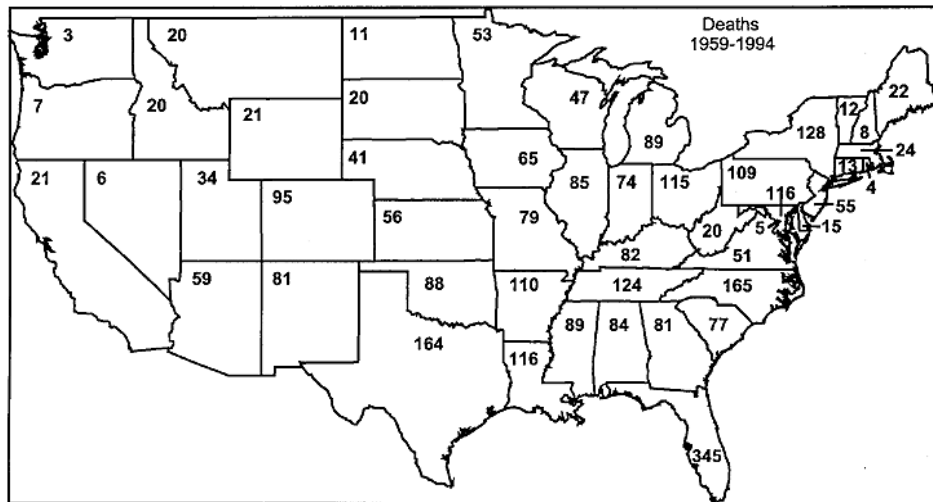
Types of Thunderstorms

- *Single Cell* (pulse storms). Typically last 20-30 minutes. Pulse storms can produce severe weather elements such as downbursts, hail, some heavy rainfall, and occasionally weak tornadoes. This storm is light to moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Multicell Cluster*. These storms consist of a cluster of storms in varying stages of development. Multicell storms can produce moderate size hail, flash floods, and weak tornadoes. This storm is moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Multicell Line*. Multicell line storms consist of a line of storms with a continuous, well-developed gust front at the leading edge of the line. Also known as squall lines, these storms can produce small to moderate size hail, occasional flash floods, and weak tornadoes. This storm is moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Supercell*. Even though it is the rarest of storm types, the supercell is the most dangerous because of the extreme weather generated. Defined as a thunderstorm with a rotating updraft, these storms can produce strong downbursts, large hail, occasional flash floods, and weak to violent tornadoes. This storm is extremely dangerous to the public and aviation.
- *Straight-line winds*, which in extreme cases have the potential to exceed 100 miles per hour, are responsible for most thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation.

Thunderstorm Facts

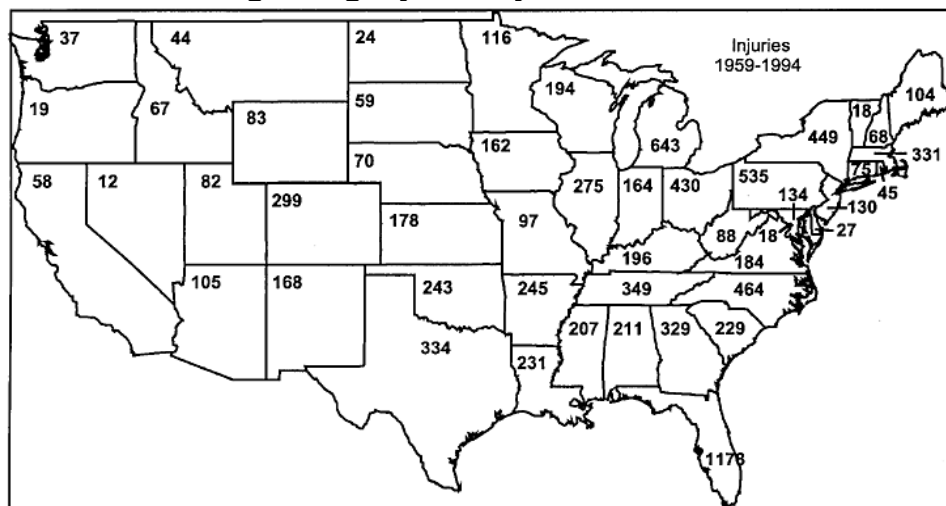
- The NWS estimates more than 100,000 thunderstorms in the U. S. each year.
- In the last 25 years, severe storms have been involved in over 300 federal disasters.

Number of lightning deaths by state from 1959 to 1994



(Source: <http://kyclim.wku.edu/climate/>)

Number of Lightning Injuries by State from 1959 to 1994



(Source: <http://kyclim.wku.edu/climate/>)

Types of Lightning

Lightning is a component of all thunderstorms. Flashes that do not strike the surface are called cloud flashes. They may be inside a cloud, travel from one part of a cloud to another, or from cloud to air. Lightning flashes can have more than one ground point. Roughly, there are five to ten times as many cloud flashes than cloud to ground flashes. Overall, there are four different types of lightning:

- Cloud to sky (sprites)
- Cloud to ground
- Intra-cloud
- Inter-cloud

Cloud to ground lightning can injure or kill people and destroy objects by direct or indirect means. Objects can either absorb or transmit energy. The absorbed energy can cause the object to explode, burn, or totally destruct. The various forms of transfer are:

- 1) Tall object transferred to person
- 2) Tall object to ground to person
- 3) Object (telephone line, plumbing pipes) to a person in contact with the appliance

Effects of Lightning

- Fires
 - Fires may occur in structures such as storage and processing units, aircraft and electrical infrastructure and components.
 - Forest fires may be initiated by lightning. Lightning causes half the wildfires in the western U.S.
- Injury and death to people
 - 85% of lightning victims are children and young men ages 10 to 35.
 - 25% of victims die and 70% of survivors suffer long-term effects.

Lightning Strike Victims, Denoted Effects			
	Frequency	25% or greater	
Memory Deficits & Loss	52% **	Depression	32% *
Attention Deficits	41% **	Inability to Sit Long	32%
Sleep Disturbance	44% *	External Burns	32%
Numbness/ Parathesias	36% **	Severe Headaches	32% **
Dizziness	38% *	Fear of Crowds	29% *
Easily Fatigued	37% *	Storm Phobia	29% *
Stiffness in Joints	35%	Inability to Cope	29% *
Irritability/ Temper Loss	34% *	General Weakness	29% **
Photophobia	34%	Unable to Work	29% **
Loss of Strength/Weakness	34% **	Reduced Libido	26% *
Muscle Spasms	34%	Confusion	25% **
Chronic Fatigue	32% *	Coordination Problems	28% **
Hearing Loss	25%		
* Denotes Psychological ** Denotes Psychological or Organic No Asterisk Denotes Organic			

(Source: <http://www.lightningsafety.com>)

Lightning Facts

- The peak temperature of lightning is around 60,000 degrees Fahrenheit, or about 5 times hotter than the surface of the Sun.
- Lightning most commonly occurs in thunderstorms, but it can also occur in snowstorms, sandstorms, and in the ejected material over volcanoes.

Severe Winter Storm

Description: A winter storm can range from moderate snow over a few hours to blizzard conditions with blinding wind-driven snow, sleet and/or ice and extreme cold that lasts several days.

A severe winter storm is defined as an event that drops four or more inches of snow during a 12-hour period or six or more inches during a 24-hour span. Severe winter storms are fueled by strong temperature gradients and an active upper-level cold jet stream. Some winter storms may be large enough to affect several states while others may affect only a single community. Most winter storms are accompanied by low temperatures and blowing snow, which can severely reduce visibility.

In the U. S.

Every state in the continental U.S. and Alaska has been impacted by severe winter storms. The super-storm of March 1993 caused over \$2 billion in property damage in twenty states and Washington D.C. At least 79 deaths and 600 injuries were attributed to the storm.

Snow and ice are threats to most of the U. S. during the northern hemisphere's winter, which begins December 21 and ends March 21. During the early and late months of the winter season, snow becomes warmer, giving it a greater tendency to melt on contact or stick to the surface. The beginning and end of the winter season also brings a greater chance of freezing rain and sleet.

Severe Winter Types

- *Blizzards* are by far the most dangerous of all winter storms. They are characterized by temperatures below twenty degrees Fahrenheit and winds of at least 35 miles per hour. In addition to the temperatures and winds, a blizzard must have a sufficient amount of falling or blowing snow. The snow must reduce visibility to one-quarter mile or less for at least three hours. With high winds and heavy snow, these storms can punish residents throughout much of the U.S. during the winter months each year. In mid-March of 1993, a major blizzard struck the Eastern U.S., including parts of Kentucky.
- *Ice storms* occur when freezing rain falls from clouds and freezes immediately on impact. Ice storms occur when cold air at the surface is overridden by warm, moist air at higher altitudes. As the warm air advances and is lifted over the cold air, precipitation begins falling as rain at high altitudes then becomes super cooled as it passes through the cold air mass below, and, in turn, freezes upon contact with chilled surfaces at temperatures of 32° F or below. In extreme cases, ice may accumulate several inches thick, though just a thin coating is often enough to do severe damage.

Possible Effects

Freezing rain can result in extensive damage to utility lines and buildings while making any type of travel extremely dangerous. The results are sometimes devastating: entire states can be almost entirely without electricity and communication for several weeks. Winter storms can paralyze a community by shutting down normal day-to-day operations. Heavy snow can also lead to the collapse of weak roofs or unstable structures. Storm effects can cause hazardous conditions and hidden problems, including the following:

- *Power outages* result when snow and ice accumulate on trees causing branches and trunks to break and fall onto power lines. Blackouts vary in size from one street to an entire city. Loss of electric power means loss of heat for some residents, which poses a significant threat to human life, particularly the elderly.
- *Extreme cold* temperatures may lead to frozen water mains and pipes, damaged car engines, and prolonged exposure to cold resulting in frostbite.
- *Flooding* may occur after precipitation has accumulated and then temperatures rise once again, which melts snow and ice. In turn, as more snow and ice accumulate the threat of flooding increases.
- *Snow and ice accumulation on roadways* can cause severe transportation problems in the form of extremely hazardous roadway conditions.

Tornado

Description: A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. It is spawned by a thunderstorm (or sometimes as a result of a hurricane) and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly.

The damage from a tornado is a result of the high wind velocity and wind-blown debris with paths that can be in excess of one mile wide and fifty miles long. Tornado season is generally March through August, although tornadoes can occur at any time of year. They tend to occur in the afternoons and evenings; over 80 percent of all tornadoes strike between noon and midnight.

Most tornadoes are just a few dozen yards wide and touch down only briefly, but highly destructive tornadoes may carve out a path over a mile wide and several miles long. The destruction caused by tornadoes may range from light to catastrophic depending on the intensity, size, and duration of the storm. Effects of tornadoes may include crop and property damage, power outages, environmental degradation, injury, and death. Tornadoes are known to blow off roofs, move cars and tractor-trailers, and demolish homes.

Typically, tornadoes are localized in impact and cause the greatest damages to structures of light construction, such as residential homes. A tornado can move as fast as 125 mph with internal wind speeds exceeding 300 mph.

The maps below illustrate the predictability of tornadic activity according to NOAA.

In the U. S.

Over the past 25 years, more than 100 federal disaster declarations included damage associated with tornadoes. On April 3, 1974, 148 tornadoes in 13 states killed 315 people and is the largest recorded tornadic event in history.

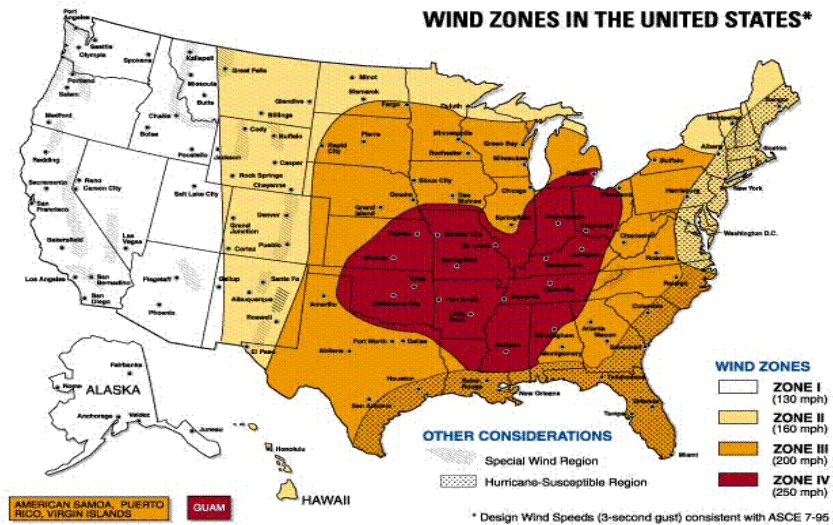


Figure I.2 Wind zones in the United States

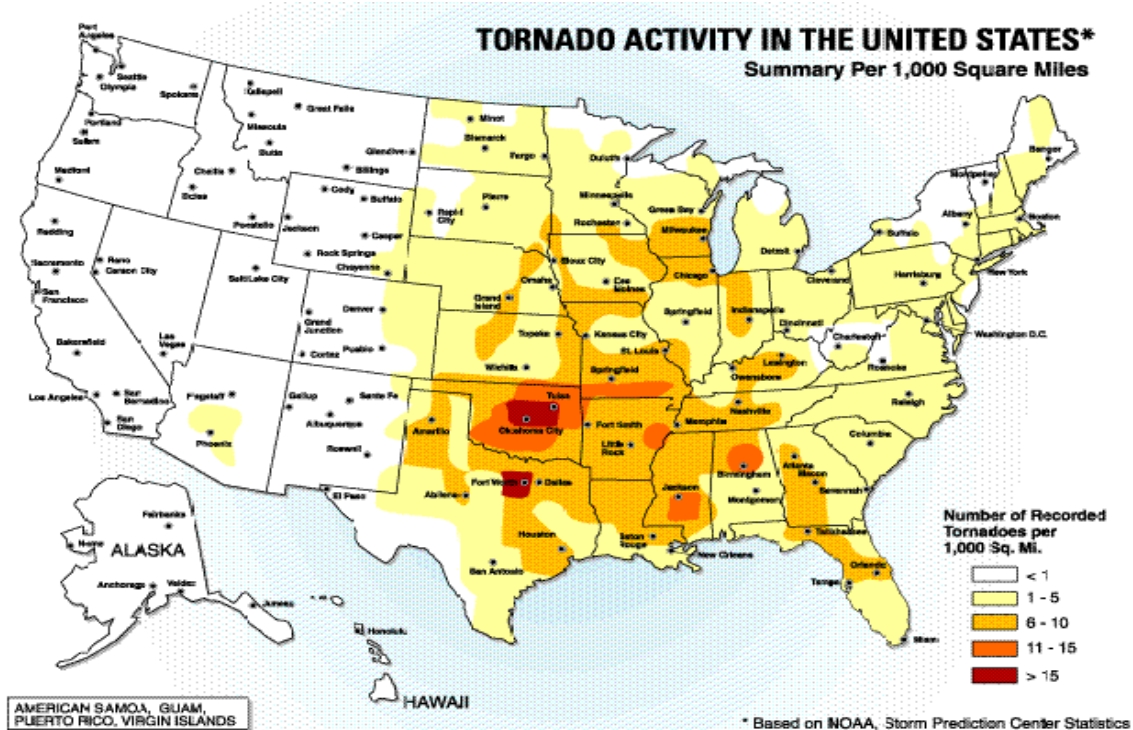


Figure I.1 The number of tornadoes recorded per 1,000 square miles

Tornado Types

The magnitude of a tornado is categorized by the damage pattern (i.e. path) and wind velocity, according to the Fujita-Pearson Tornado Measurement Scale. This scale is the only widely used rating method with the aim to validate classification by relating the degree of damage to the intensity of the wind.

The Fujita Scale for Tornadoes		
Type	MPH	General Description
F1	73 - 112	Moderate Damage - Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113 - 157	Considerable Damage - Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light object missiles generated; cars lifted off ground.
F3	158 - 206	Severe Damage - Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207 - 260	Devastating Damage - Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261 - 318	Incredible Damage - Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur.

Source: FEMA State and Local Mitigation Planning How-To-Guide: Understanding Your Risks)

Thunderstorm Facts

- Worldwide, annually about 1,000 tornadoes are generated by severe thunderstorms.
- Earthquake-induced fires and wildfires may also produce tornadoes.
- Powerful tornadoes have lifted and moved objects weighing more than 300 tons a distance of thirty feet and have tossed homes greater than 300 feet way from their foundations.
- The path of a single tornado can be dozens of miles long, but tornadoes rarely last longer than 30 minutes.

Wildfire

Description: A wildfire is an unplanned fire, which includes grass fires, forest fires, and scrub fires either man-made or natural in origin. There are three different classes of wildland fires. A *wildfire* is an uncontrolled burning of grasslands, brush, or woodlands.

Humans, either through negligence, accident, or intentional arson, have caused approximately 90% of all wildfires in the last decade. Accidental and negligent acts include unattended campfires, sparks, burning debris, and irresponsibly discarded cigarettes. The remaining 10% of fires are mostly caused by lightning, but may also be caused by other acts of nature such as volcanic eruptions or earthquakes.

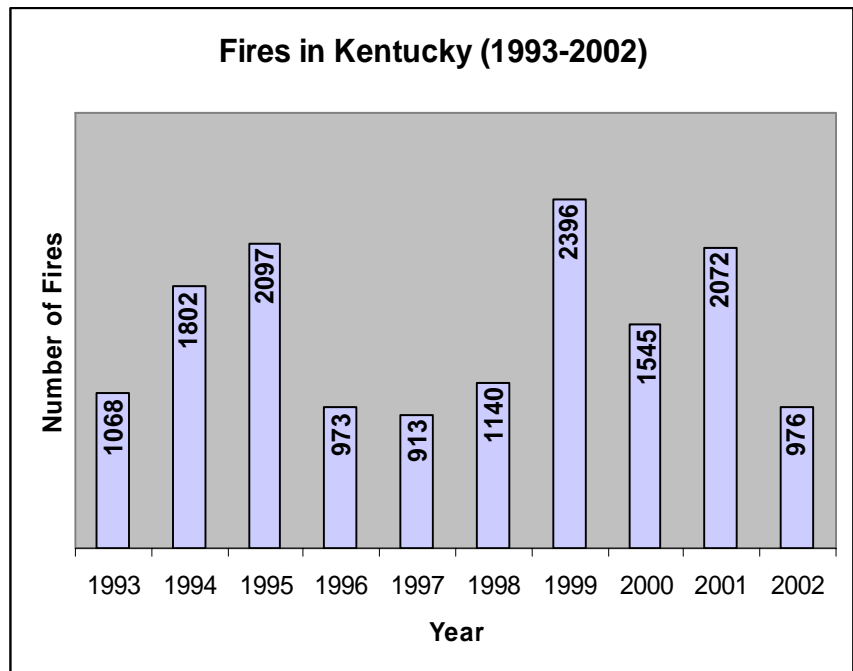
In the U. S.

According to the NWS, more than 100,000 wildfires occur in the U. S. each year. Since 1985, approximately 9,000 homes have been lost to urban / wild land interface fires across the U. S.

Wildfires become significant threats to life and property along what is known as the “wildland/urban interface”. The wildland/urban interface is defined as the area where structures and other human development meet or intermingle with undeveloped wild land or vegetative fuels.

Source: Kentucky Division of Forestry www.forestry.ky.gov/programs/firemanage/Fire+Statistics.htm

The potential for wildfire depends upon surface fuel characteristics, weather conditions, recent climate conditions, topography, and fire behavior. Fuels are anything that fire can and will burn, and are the combustible materials that sustain a wildfire. Typically, this is the most prevalent vegetation in a given area. Weather is one of the most significant factors in determining the severity of wildfires. The intensity of fires and the rate with which they spread is directly related to the wind speed, temperature, and relative humidity. Climatic conditions such as long-term drought also play a major role in



the number and intensity of wildfires, and topography is important because the slope and shape of the terrain can change the rate of speed at which fire travels.

Wildfire Types

- *Surface fires* are the most common type and burn along the floor of a forest, moving slowly and killing or damaging trees.
- *Ground fires* are usually started by lightning and burn on or below the forest floor.
- *Crown fires* spread rapidly by wind and move quickly by jumping along the tops of trees.
- *Spotting* can be produced by crown fires as well as wind and topography conditions. Large burning embers are thrown ahead of the main fire. Once spotting begins, the fire will be very difficult to control.

Possible Effects

Wildland fires are usually signaled by dense smoke that fills the area for miles around. The average forest fire kills most trees up to 3-4 inches in diameter, in the area burned. These trees represent approximately 20 years of growth. In the case of up-slope burning, under severe conditions, almost every tree is killed regardless of size or type. When the trees are burned and everything is killed, then the forest is slow to reestablish itself, because of the loss of these young seedlings, saplings, pole, and sawtimber trees.

Included in the destruction by fires are the leaf and other litter on the forest floor. This exposes the soil to erosive forces, allowing rainstorms to wear away the naked soil and wash silt and debris downhill, which will clog the streams and damage fertile farmlands in the valleys. Once the litter and humus (spongy layer of decaying matter) is destroyed, water flows more swiftly to the valleys and increases flood danger.

Other consequences of wildfires are the death of and loss of habitat for the forest's wildlife. The heaviest wildlife lost is felt by game birds since they have ground nesting habits. Fish life also suffers because of the removal of stream shade and the loss of insect and plant food is destroyed by silt and lye from wood ashes washed down from burned hillsides.

Wildfire Fuel Categories

- *Light fuels* such as shrubs, grasses, leaves, and pine needles (any fuel having a diameter of one-half inch or less) burn rapidly and are quickly ignited because they are surrounded by plenty of oxygen. Fires in light fuels spread rapidly but burn out quickly, are easily extinguished, and fuel moisture changes more rapidly than in heavier fuels.
- *Heavy fuels* such as limbs, logs, and tree trunks (any fuel one-half inch or larger in diameter) warm more slowly than light fuels, and the interiors are exposed to oxygen only after the outer portion is burned.

- *Uniform fuels* include all of the fuels distributed continuously over an area. Areas containing a network of fuels that connect with each other to provide a continuous path for a fire to spread are included in this category.
- *Patchy fuels* include all fuels distributed unevenly over an area, or as areas of fuel with definite breaks or barriers present, such as patches of rock outcroppings, bare ground, swamps, or areas where the dominant type of fuel is much less combustible.
- *Ground fuels* are all of the combustible materials lying beneath the surface including deep duff, tree roots, rotten buried logs, and other organic material.
- *Surface fuels* are all of the combustible materials lying on or immediately above the ground, including needles or leaves, duff, grass, small deadwood, downed logs, stumps, large limbs, and low shrubs.
- *Aerial fuels* are all of the green and dead materials located in the upper canopy, including tree branches and crowns, snags, hanging moss, and tall shrubs.

Fuel Types

- *Grass.* Found in most areas, but grass is more dominant as a fuel in desert and range areas where other types of fuel are less prevalent. It can become prevalent in the years after a fire in formerly timbered areas.
- *Shrub (brush).* Shrub is found throughout most areas of the U.S. Some examples of highly flammable shrub fuels are the palmetto/ gallberry in the Southeast, sagebrush in the Great Basin, and chaparral in the Southwest.
- *Timber litter.* This type of fuel is most dominant in mountainous topography, especially in the Northwest.
- *Logging slash.* This fuel is found throughout the country. It is the debris left after logging, pruning, thinning, or shrub-cutting operations. It may include logs, chunks, bark, branches, stumps, and broken understory trees or shrubs.

Fuel Characteristics

- *Fuel moisture* is the amount of water in a fuel. This measurement is expressed as a percentage. The higher the percentage, the greater the content of moisture within the fuel. How well a fuel will ignite and burn is dependent, largely, on its moisture content. Dry fuels will ignite and burn much more easily than the same fuels when they are wet (contain a high moisture content). As a fuel's moisture content increases, the amount of heat required to ignite and burn that fuel also increases. Light fuels take on and lose moisture faster than heavier fuels. Wet fuels have high moisture content because of exposure to precipitation or high relative humidity, while dry fuels have low moisture content because of prolonged exposure to sunshine, dry winds, drought, or low relative humidity.

Wildfire Facts

- Homeowners can do much to help save their homes from wildfires, such as constructing the roof and exterior structure of a dwelling with non-combustible or fire resistant materials such as tile, slate, sheet iron, aluminum, brick or stone.

One of the worst wildfire seasons, in terms of number of acres burned, was 2000 when wildfires burned 8.4 million acres. Scientific analysis of the 2000 fire season revealed that the vast majority of burned acres were located in previously logged and roaded areas. The worst fire seasons were in 1963, 1988, and 2004.